Advanced BHA Modeling and Drilling & Evaluation Technology to Improve Efficiency in Shale Gas Horizontal Drilling

Shale Gas Typical Drilling Challenges

Challenge /Objective	Impact
Performance Optimization	Reduced ROP, Days on Well
Wellbore Placement	Production Optimization
Bit & Motor Durability	Bit Trips – NPT
Excessive Sliding	Reduced ROP, Days on Well
Extended Reach	Production Optimization
Borehole Quality	Problems Run CSG, Red. ROP
PDC Bit Vibrations	Reduced ROP, Days on Well
High Stick-Slip, Torque	Reduced ROP, Days on Well
Staying in Zone (Lateral)	Production Optimization
Hole Cleaning, Balling	Reduced ROP, Days on Well
Pack Offs, Stuck	Increased Days on Well
Faulted/NF, Abrasive Format.	Reduced ROP, Days on Well

Major Shale Gas Drilling Challenges:

- The formations are difficult – maximize the trip time
- Optimize drilling to increase ROP
- How to steer to the right place in the formation

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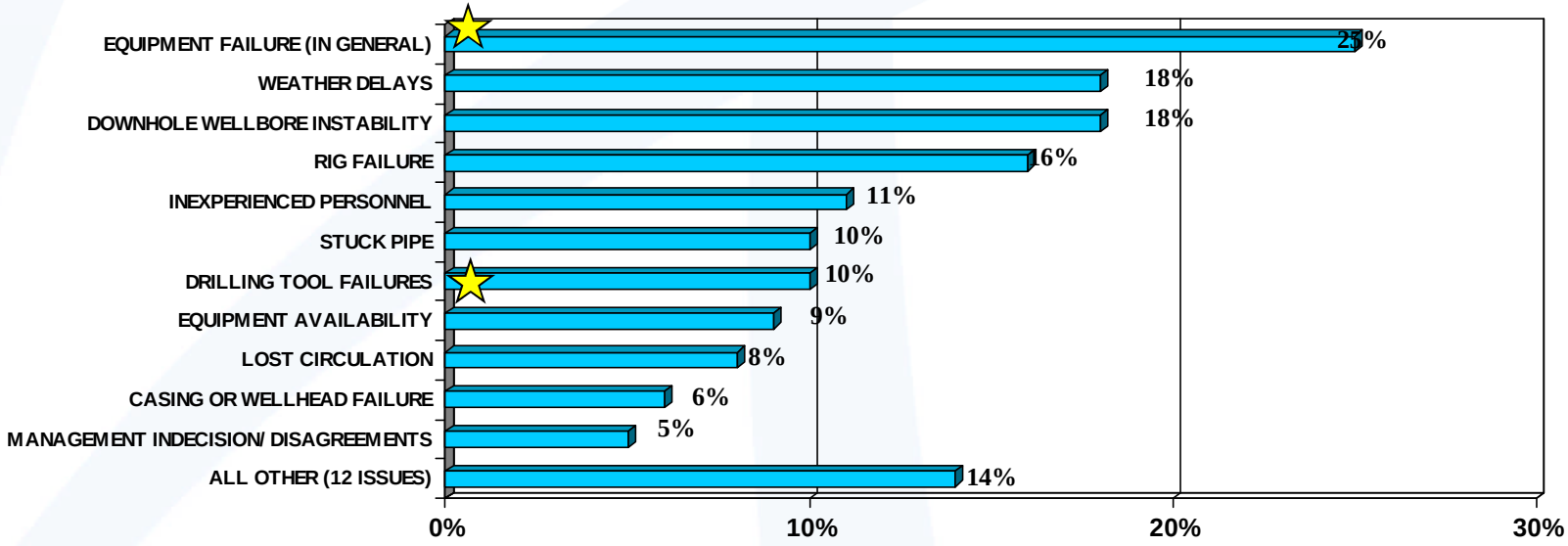
The Value of Bit and BHA Stability

Drilling system stability has a significant influence on overall reliability (i.e. less vibration = less bit, BHA, and drill string damage)

- Equipment failure is the largest source of non-productive time
- Drilling tool failures specifically cited as a top source for NPT

Survey Question: What is your greatest source of NPT?



Source: Welling & Company

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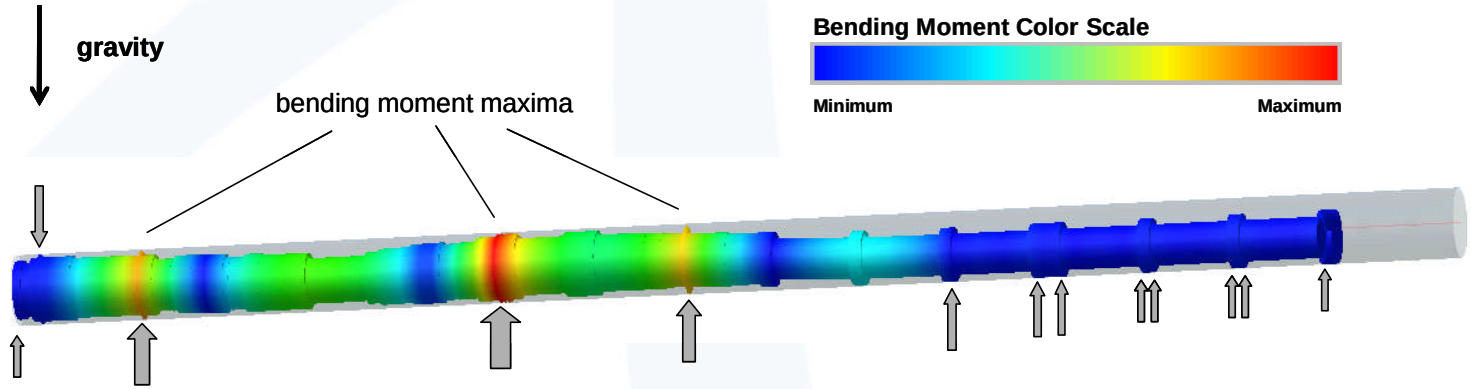
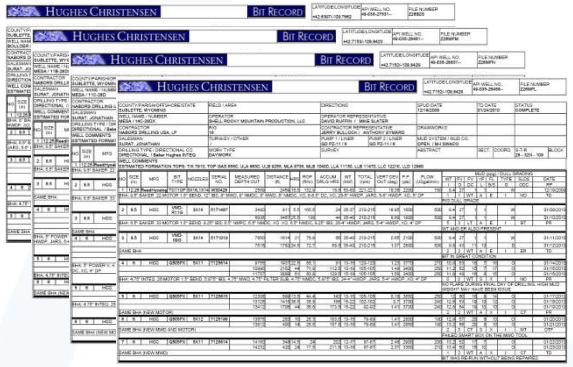
Drilling Engineering / Optimization

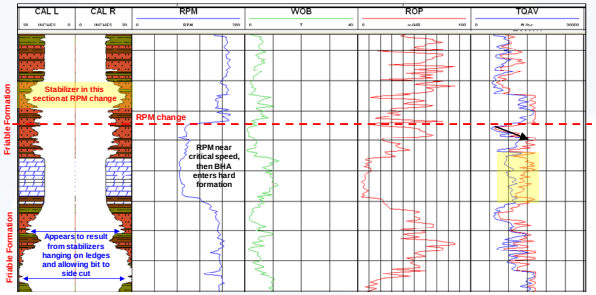
- Internal education and certification program for Drilling Application Engineers
- AKS - Application Knowledge Store
- Advantage Engineering Package
  - Torque & Drag, Hydraulics
- BHASysPro Analysis Software



Reducing Days on Well by Drilling Optimization

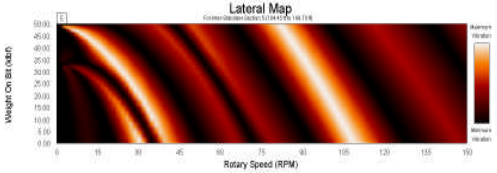
Offset Well and Dull Bit Analysis



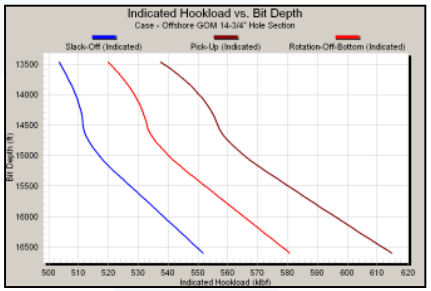


Downhole Tools, Analytical Tools and Modeling

BHA Modeling



Torque, Drag, Hydraulics Modeling



Downhole dynamics measurement

DF Designs & ECD

Structured Processes & Engineering Training

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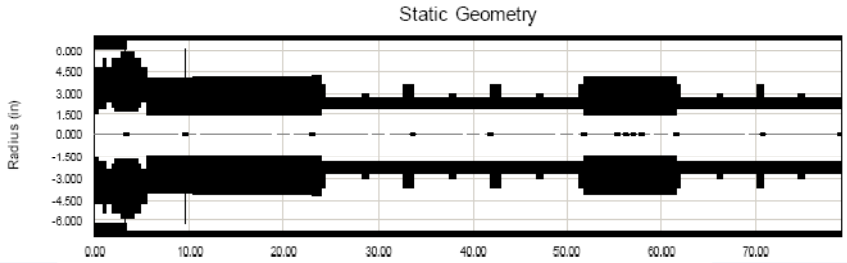
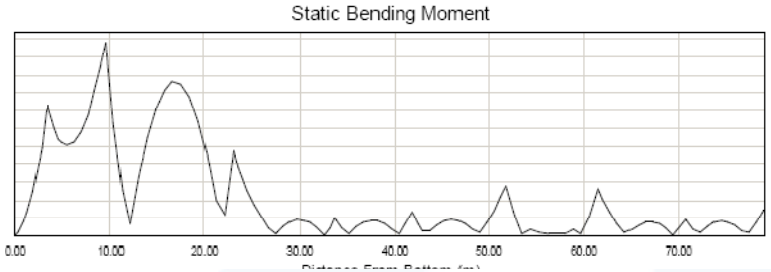
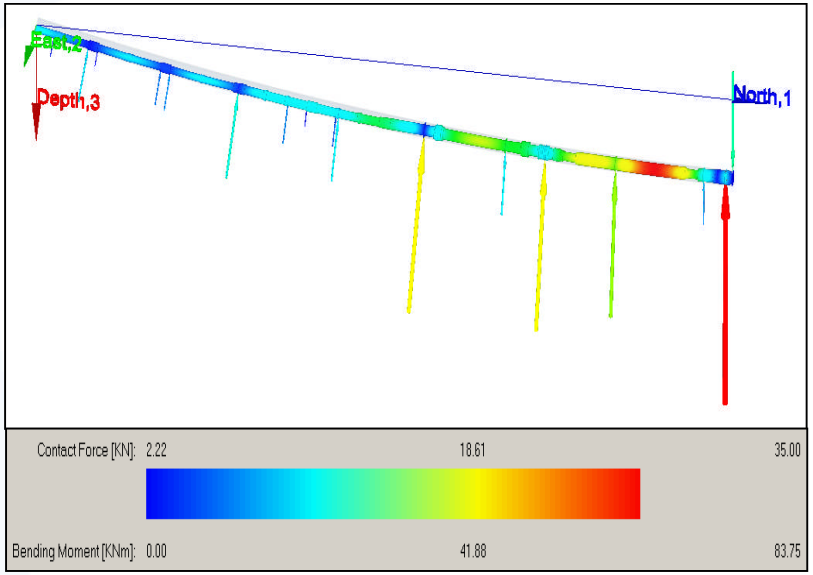
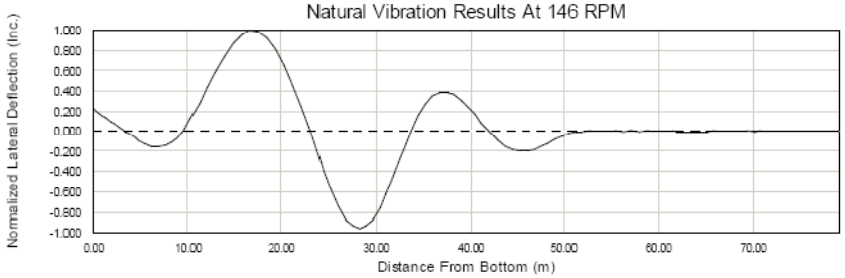
BHASysPro - Fit for Purpose BHA









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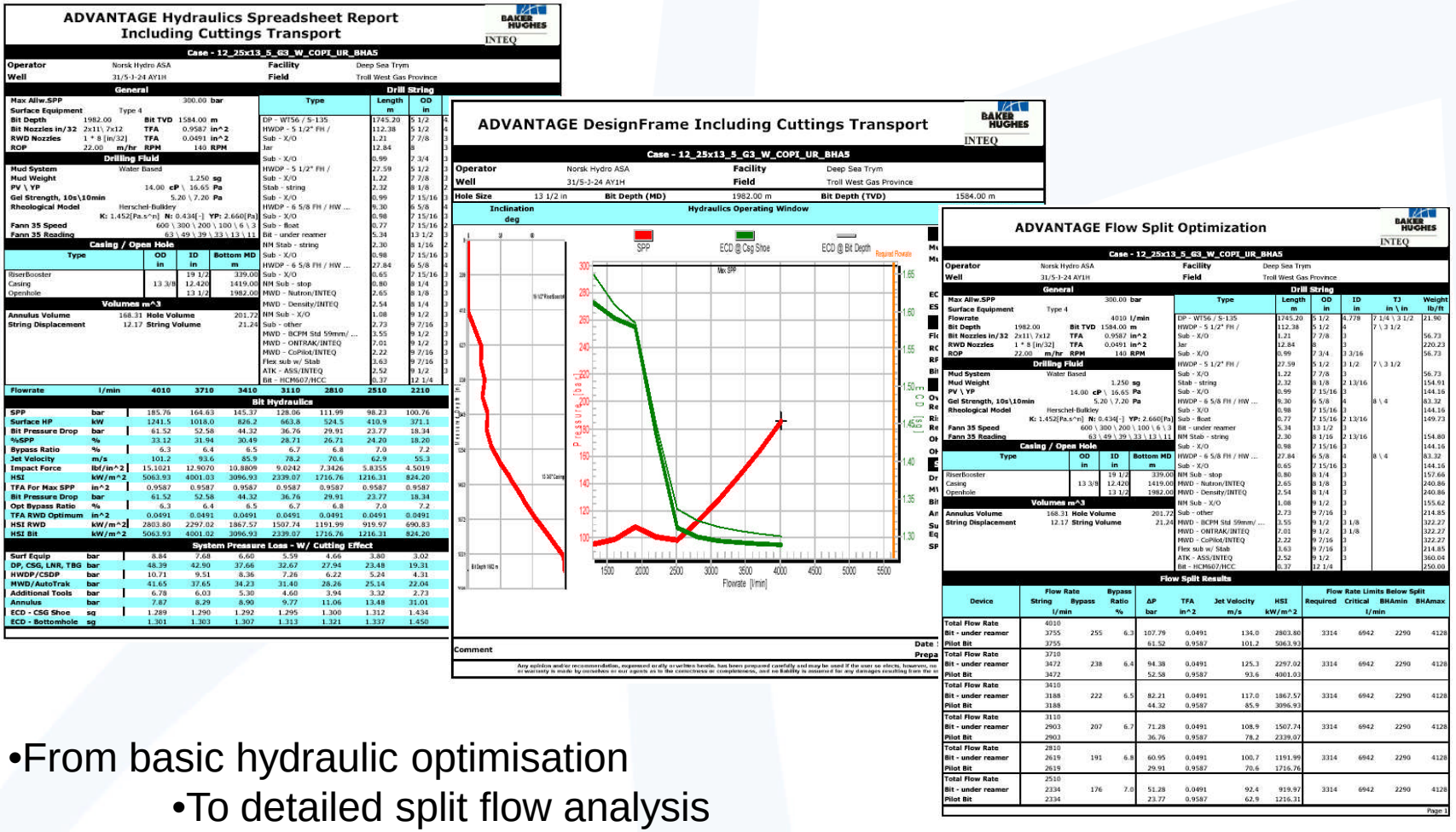
Advantage Software for Hydraulic Optimization



ADVANTAGE Hydraulics Spreadsheet Report
Including Cuttings Transport

ADVANTAGE DesignFrame Including Cuttings Transport

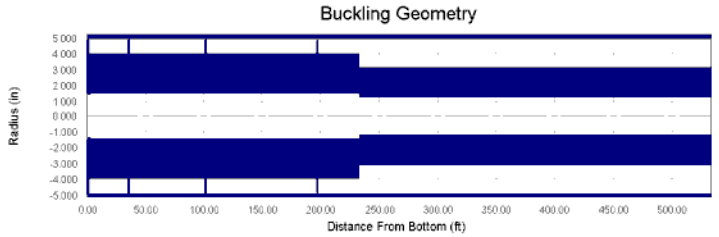
ADVANTAGE Flow Split Optimization

- From basic hydraulic optimisation
  - To detailed split flow analysis
    - To guarantee flawless deployments

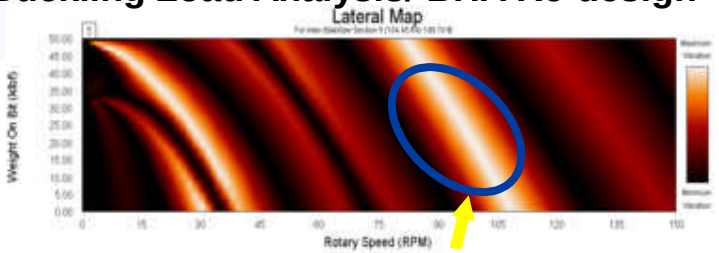
Going farther faster – Drilling Optimization (Barnett Shale example)

Drilling Challenges

- Premature Damage to PDC Bits
- Low ROP, More Bits Required
- High Cost Per Foot
- High Torque and Drag
- Excessive Slide Drilling (Oriented) in Lateral Interval
- Damaging Drill String Vibrations
- Low Reliability/Performance of Downhole Tools

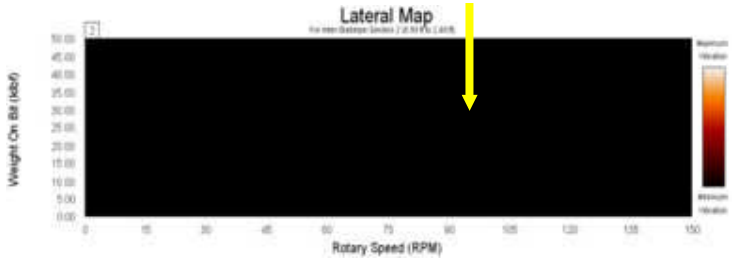


Buckling Load Analysis/ BHA Re-design



Away from Bit - High Vibration

Closer to Bit - Minimum Vibration



Critical Speed Analysis – Optimize Drilling Parameters

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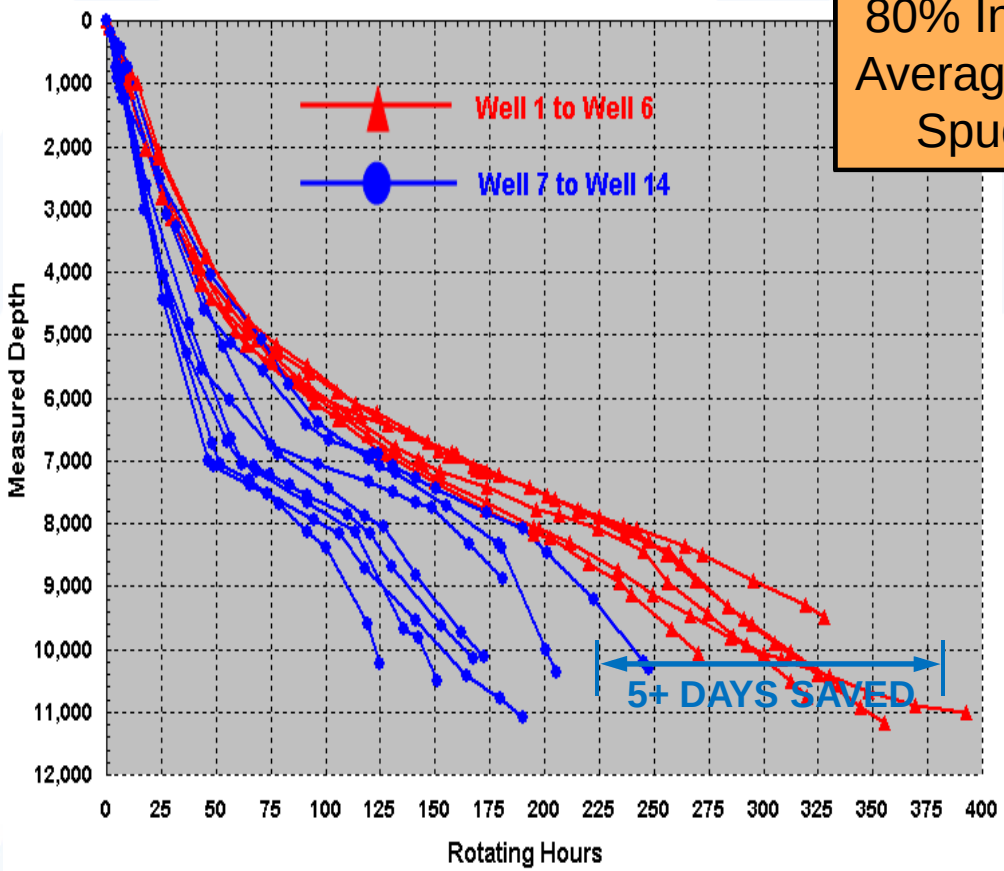
Drilling Optimization (Barnett Shale Example)



80% Increase in Average ROP for Spud to TD

Optimization

- Modified PDC Bits
- Model Re-design BHA
  - torque, drag, hydraulics
- Optimized Parameters - WOB, Rotation
- Critical Speed Analysis to reduce vibration
- Result - increase ROP

6 Wells Drilled Prior to Optimization @ 32 ft/hr
8 Wells Drilled After Optimization @ 57 ft/hr

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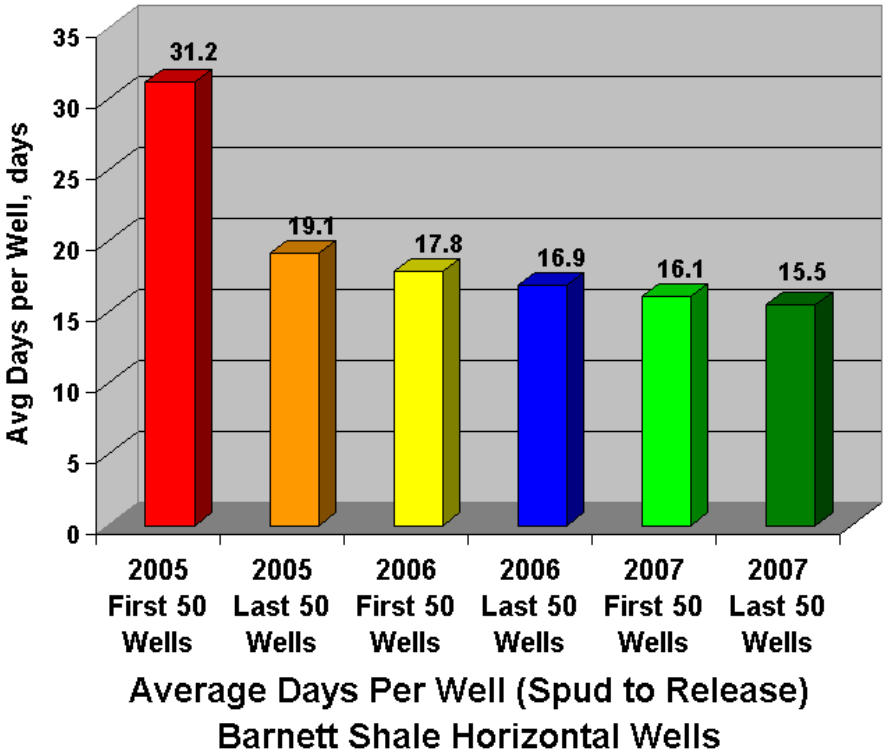
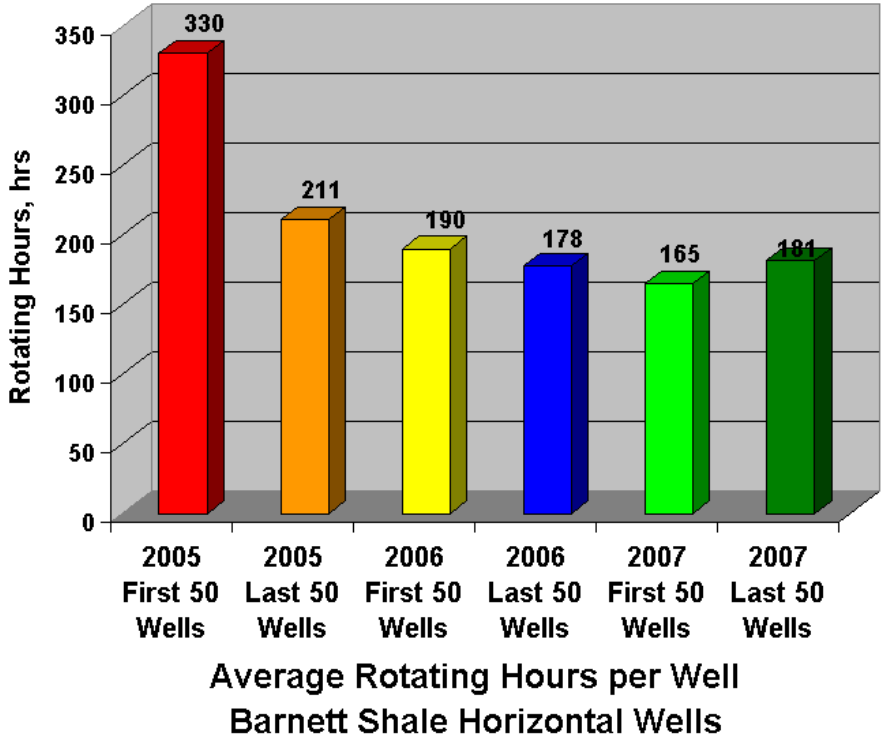
Barnett Shale – Drilling Performance



Average days per well reduced from 31.2 to 15.5 days



Average rotating hours per well reduced from 330 to 181 hours

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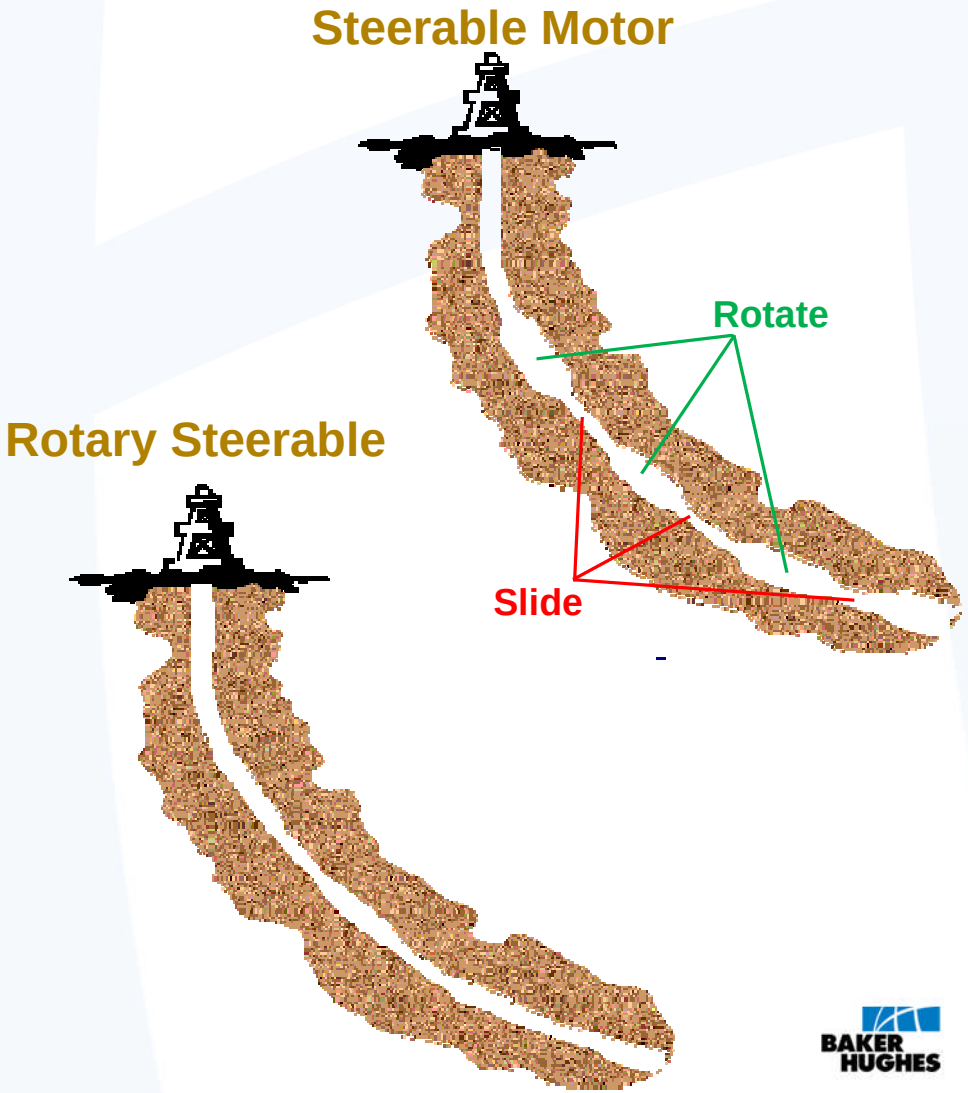
Decrease risk and reduce time on well utilizing Rotary Steerable Tools – Shale Gas Laterals

- Decrease risk
  - Improved borehole quality allows for casing running operations to be completed with less risk for extended reach laterals
- Reduce time on well
  - Eliminating orient and slide time associated with steerable motor drilling improves overall effective penetration rate



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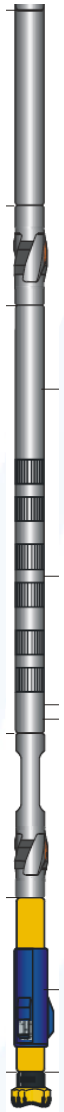
Eagle Ford - Webb County – AutoTrak G3 / OnTrak

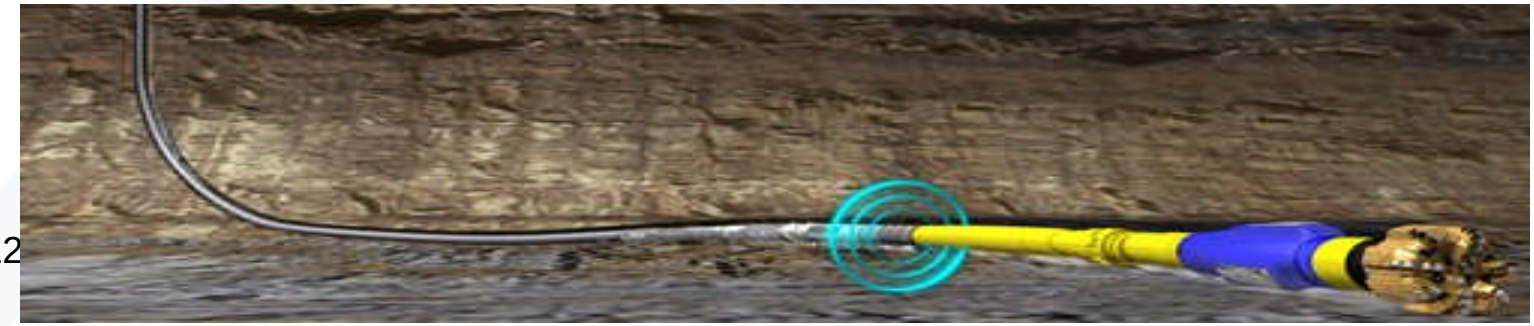


Well Details
- Well Details
- Location: Webb County
- Shale Play: Eagle Ford
- Hole Size: 8 ¾” Curve and Lateral

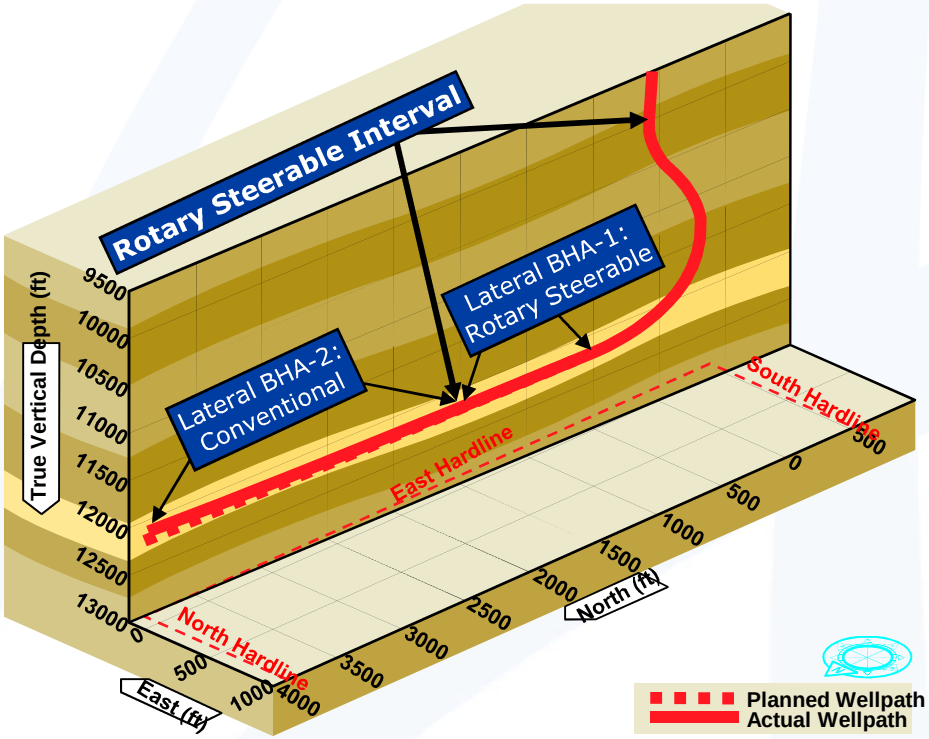
Challenges
- Low ROP’s
- Several Bits Required
- Inconsistent BUR’s in Curve
- Trips to change BHA’s
- Reduced Drilling Efficiency
- High Cost per foot
- Difficulties staying in Zone

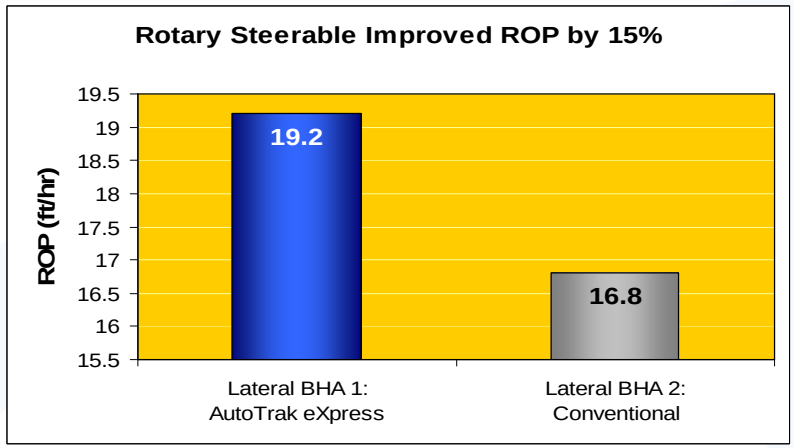
Solution
- 8 ¾” HCC Bit (DP505X PDC Bit)
- 6 ¾” AutoTrak G3 RSS
- 6 ¾” OnTrak LWD

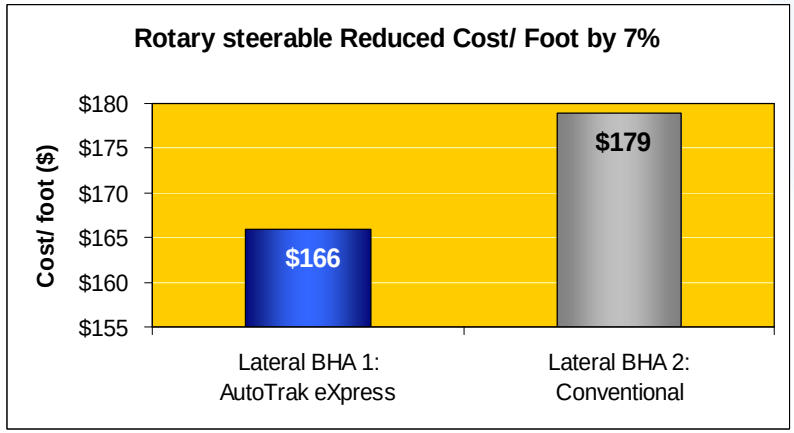
Project Results
- Drill Curve from 23 deg inclination and land the curve
- Continue Drilling Entire Lateral of 3,748 ft to TD
- Total Footage: 5,113 ft
- Rotating Hrs : 97.75 hrs
- Average ROP: 52.3’/hr
- Eliminated Reaming
- Smoothly Ran Liner to Bottom
- Consistent BUR’s
- Stayed in Desired Zone



Woodford Shale – Rotary Steerable

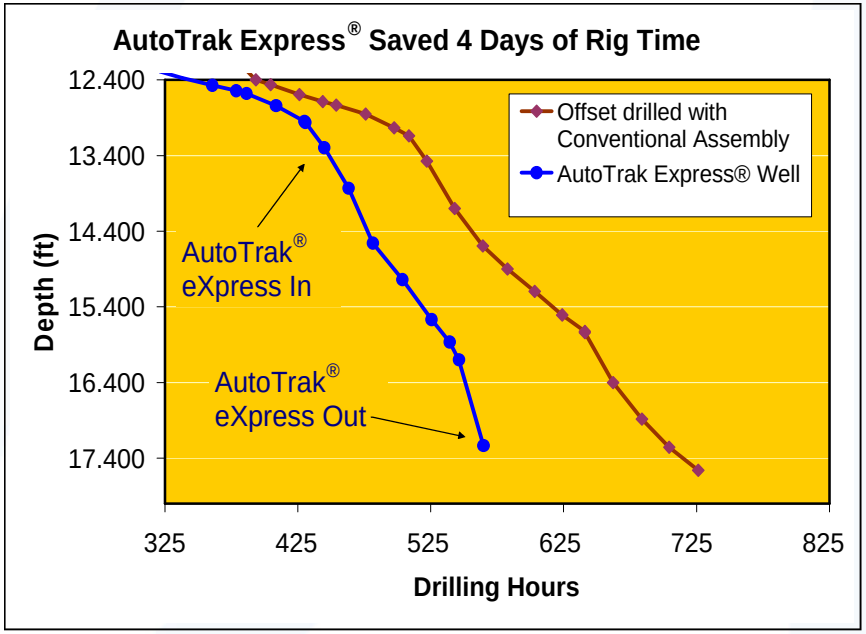


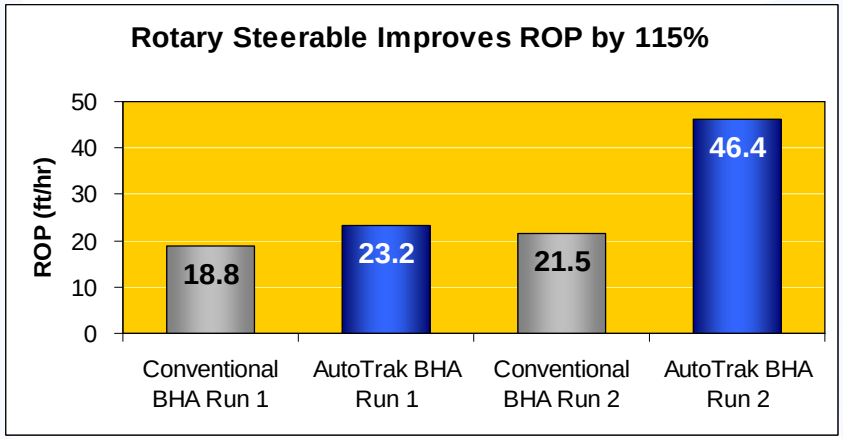


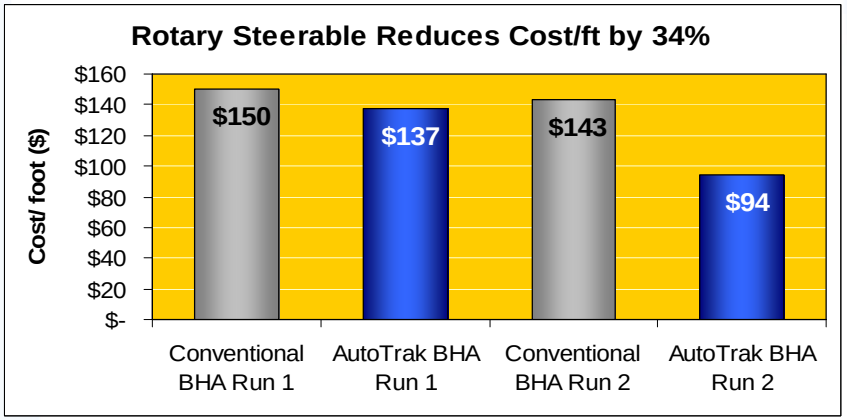


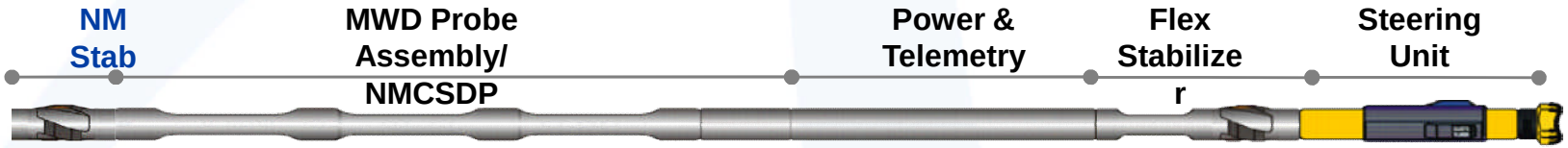
Woodford Shale – Rotary Steerable

AutoTrak™ eXpress
Automated Rotary Steerable Drilling









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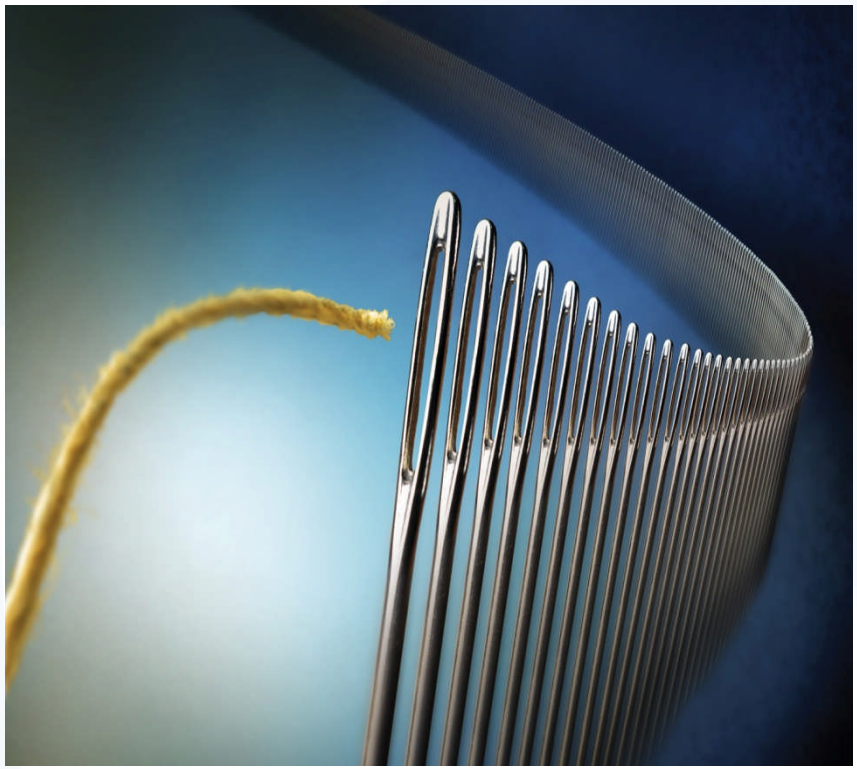
Maximizing production by optimizing wellbore placement –Shale Gas

- Reservoir Navigation
  - Full suite of formation evaluation tools and services to steer to the reservoir “sweet spot”



Reservoir Navigation – Woodford Shale

Project Results

- Well was maintained in target zone
- Reservoir Navigation Services
- Multiple Propagation Resistivity
- Azimuthal Gamma Ray
- Gamma Ray Imaging
- Annular and Bore hole pressure

Fig. 2: Gamma Image of Well A

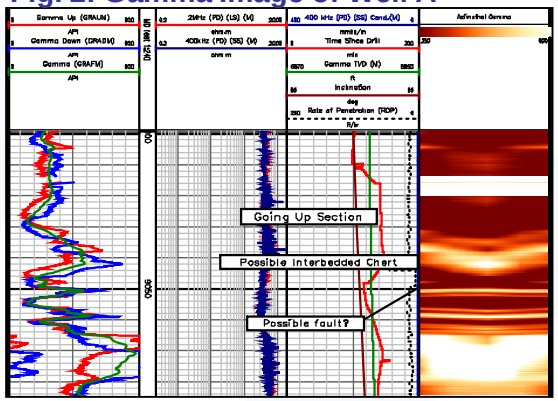


Fig. 4: Gamma Image of Well B

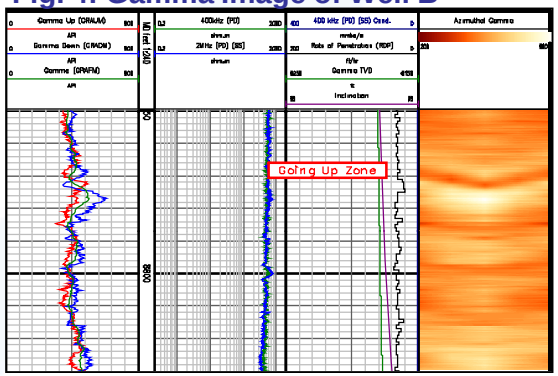


Fig.1: RNS CROSS SECTION – Well A

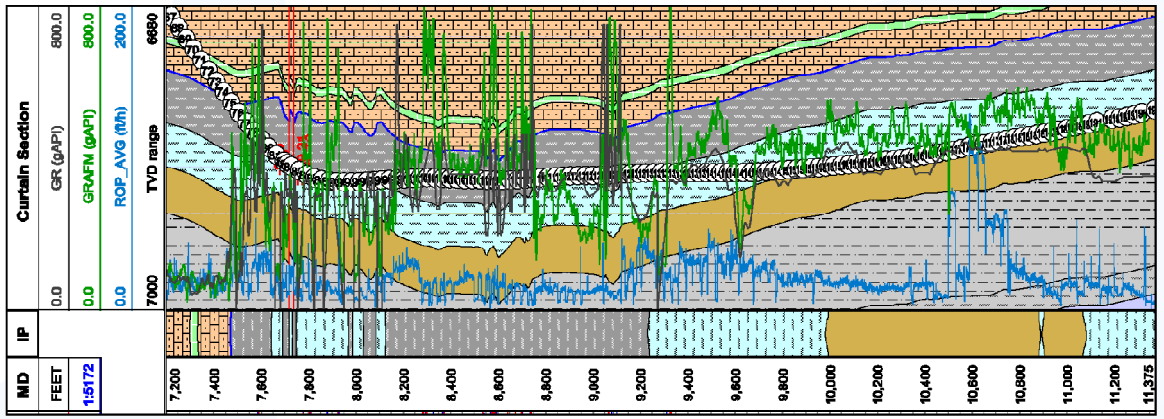
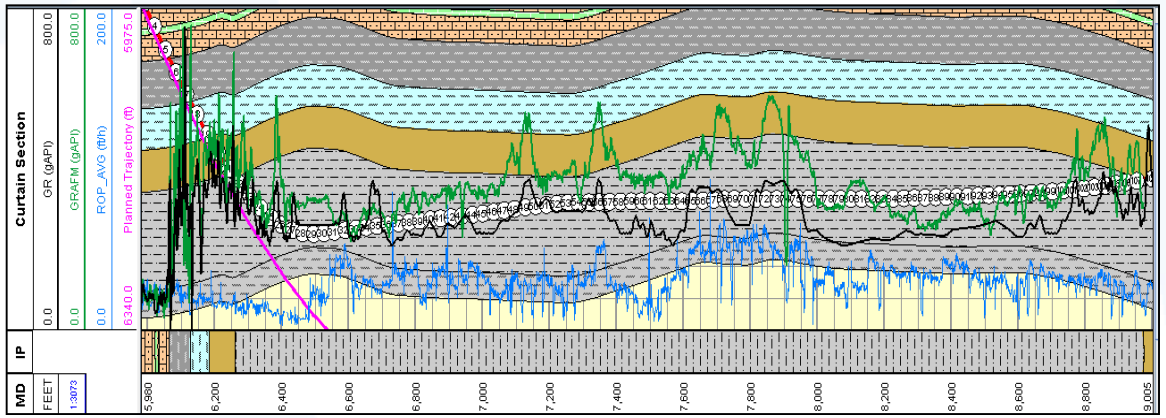


Fig.3: RNS CROSS SECTION – Well B



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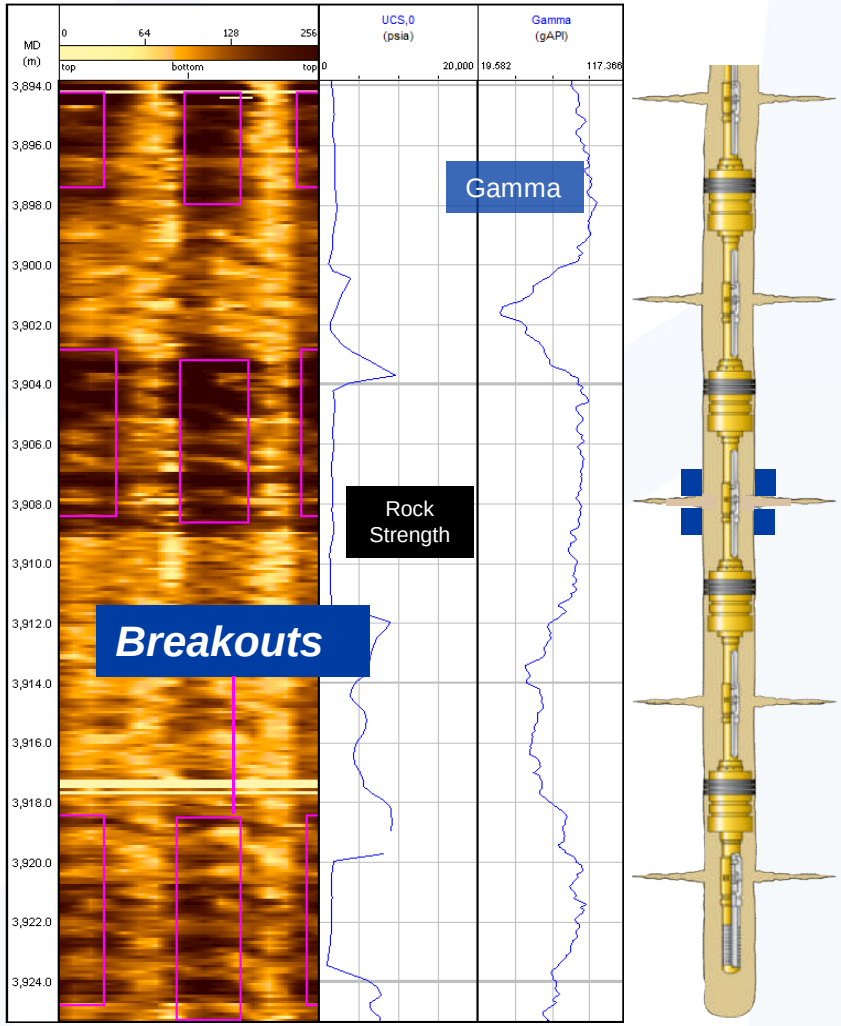
LWD Image in Shale Gas

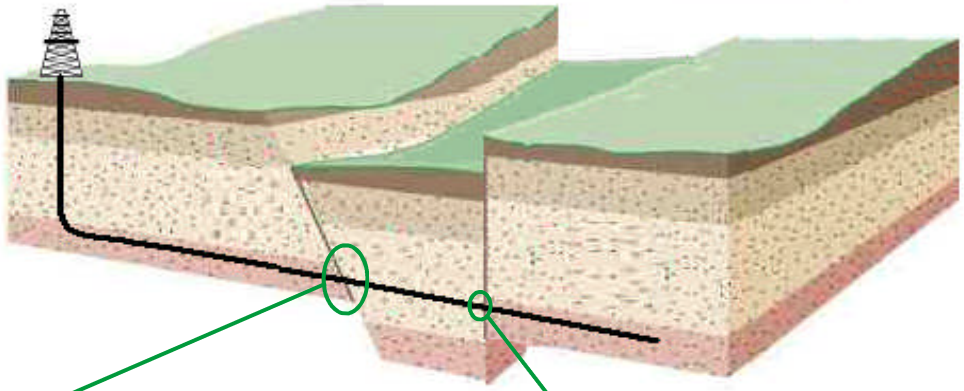


LWD Can be used to identify:

- Fracture
- Lithoface good for fracturing
- Optimization of perforating interval
- Optimization of packer placement
- Fracturing length

Integrated fracturing design

Faults and Fractures in Barnett Shale Horizontal Well



Barnett Shale

Forestburg Carbonate

Forestburg Carbonate

Barnett Shale


Thank You